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SUGGESTED AREAS FOR MODIFICATION OR DEVELOPMENT  
OF VEHICLES AND EQUIPMENT FOR URBAN MILITARY OPERATIONS OVERSEAS

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## FOREWORD

This note was prepared in response to a request to the Institute for Defense Analyses from the Office of the Deputy Director for Defense Research and Engineering (Tactical Warfare Programs) for an investigation of the problems confronting military units in overseas urban warfare. The principal response to that request is contained in IDA Study S-345, Promising Areas of Research and Development for Tactical Operations in an Overseas Urban Environment. This note supplements Study S-345.

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## ABSTRACT

This note identifies modifications and developments in vehicles and equipment to facilitate their use for combat in overseas cities and suggests physical and analytical models for testing and evaluating such equipment; road clearance and maintenance; locomotion; demolition; reconnaissance, search and destroy; wall and building scaling; threat neutralization; sanitation; detection of underground passageways and utility lines; ferret vehicles; and surveillance by lighter-than-air craft.

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## I. GENERAL

Combat in the cities of today's "emerging" nations as well as in industrialized nations presents many difficult problems due in no small measure to the structure of the cities themselves, some of which have inhabited sections constructed many hundreds of years ago. Political, economic, religious, historical and architectural characteristics vary widely with geographic locality and time of construction, contributing to complexities in planning and training for urban conflict. It is intended here to address problems that are primarily hardware oriented. However, some indication of the framework within which the problems are approached would seem useful.

Larger and larger segments of the world population are becoming urbanized. Political, economic, and physical control of population under conditions of limited warfare is directly related to control of events and conditions leading up to and during combat, i.e., plebiscities, pacification and peace keeping, rescue and relief, evacuation, protection, urban disorder, urban insurgency, urban guerrilla war, and limited war. In many instances the type of military force applied and the manner of application will be subject to an assessment of the relative importance of military objectives, political expediency, and economic impact. This being the case, the visible characteristics of the military forces assigned to urban combat will in some measure influence urban populations as regards cooperation, passivity, counter activity, and so forth.

In order to achieve an understanding of the organic composition of the equipment necessary to meet mobility and transport requirements of a regular military force engaged in urban combat, one must address the primary missions and the various tasks to be performed in

implementing those missions. Mission objectives are best understood in the subjective terms of scenarios and specific tasks, which, in turn, focus attention on the kinds and quantities of weapons and support equipment an urban combat force requires. This would suggest a study directed at the development of an "urban brigade" (possibly similar to the development of the air cavalry concept). A study of this magnitude is not intended here. The current effort is directed at identifying some of the areas where urban combat effectiveness may be improved by modifying existing equipment to better match the urban environment or by employing available technology to improve equipment. Stated more succinctly, interest is centered on improving the tools available for conducting urban warfare at the several levels of combat intensity that are likely to occur.

As a general premise one might say that rapid movement of men, weapons and materials under the full range of conditions that may be encountered in urban warfare is necessary in order to successfully carry out tactical objectives and maintain population control with minimum economic disruption. This requires transit before, during and after combat over streets cratered by explosives, littered with debris, blocked or barricaded with barbed wire and masonry, and booby trapped or mined. It also requires a capability to quickly clear debris and obstacles and make sufficient road surface repairs for essential civil as well as military transport. The vehicles and equipment generally available for these tasks have been those developed for combat in rural, open and rough country environments on the one hand, and for commercial and industrial transport and construction on the other. The extent to which combat in an urban environment has been considered in designing any of these vehicles appears to be limited. The following sections attempt to address problems encountered in the past during conflict in cities.

## II. PHYSICAL ENVIRONMENTAL AND TERRAIN MODELS FOR URBAN CONFLICT

A major factor in developing combat vehicles and equipment effective in rural, open and rough country has been the availability and use of full-scale real-time models--swamps, rivers, creeks, ravines, meadows, deserts, forests, mountains, for example--to which performance requirements could be related and on which vehicles and equipment could be tested and evaluated. If serious consideration is to be given to stressing vehicle and equipment requirements for urban combat, then consideration should also be given to providing the kind of full-scale environmental models necessary for development and dynamic test of the urban combat vehicles and equipment.

One approach to filling the need for suitable environmental models would be to consider the use of full-scale physical models. It is suggested that several typical urban area models could be constructed. Models would be representative of particular world geographic areas in which our forces are likely to become engaged during a time period equivalent to the development and deployment cycle of a next-generation weapon system or equipment. Basic habitable units--rooms, hallways, and the like--would be full size. Floor area per story and number of stories per structure could be reduced so long as the size of the structure and the type of construction remained representative and the tactical problems of urban combat could be effectively reproduced. The urban models could be limited to several city blocks or partial blocks. Such features as dimensions and type of construction of streets would be particularly important as would some categories of underground facilities such as storm sewers, service conduits or other potential means of clandestine transit and communication. Interior finish of structures and utility service could be minimized in the interest of costs.



The purpose of the proposed urban models would be to promote development of vehicles and equipments that emphasize performance characteristics pertinent to the various levels of conflict that a military force might encounter in urban areas. During equipment and vehicle tests, the urban models could, in fact, provide specific controlled environments in which to exercise the equipments. This use of urban models would serve as a means of evaluating such factors as weapon effectiveness, vehicle mobility, utility of special equipment, and capability to maintain and reopen lines of communication, supply and transit. (It is evident that sections of models could be destroyed and rebuilt many times. Accordingly these models could serve a useful purpose in providing a service "school" for training men interested in various facets of the construction trades for a useful civilian career.)

A number of conditions and circumstances that occur or seem likely to occur in urban conflicts suggest the need to focus attention on performance characteristics that are responsive to the urban environments. Basically the tools of warfare for urban conflicts are the same as for waging war in rural or open country. However, there may be differences in constraints and priorities which should be reflected in equipment design and performance.

Use of real-time physical models of urban areas as a framework within which equipment and vehicles must operate and against which performance can be tested and requirements ordered to reflect relative importance in the context of urban combat (as compared to combat in rural or open country) is not viewed as likely to induce many inventions of new concepts or configurations of equipment or vehicles. The anticipated advantages are expected to be embodied in tailored designs wherein equipments and vehicles incorporate combinations of features arrived at by a better understanding of the problems, sounder trade-off and preliminary design studies, more appropriate use of advances in applicable technology, and good engineering practices.

#### A. PHYSICAL FULL-SCALE URBAN ENVIRONMENT AND TERRAIN MODELS

The costs of two urban area models were estimated based on current material and labor costs and typical construction methods. One model is for a commercial area and one model is for a residential area. The areas covered in each model are shown in Figure 1.

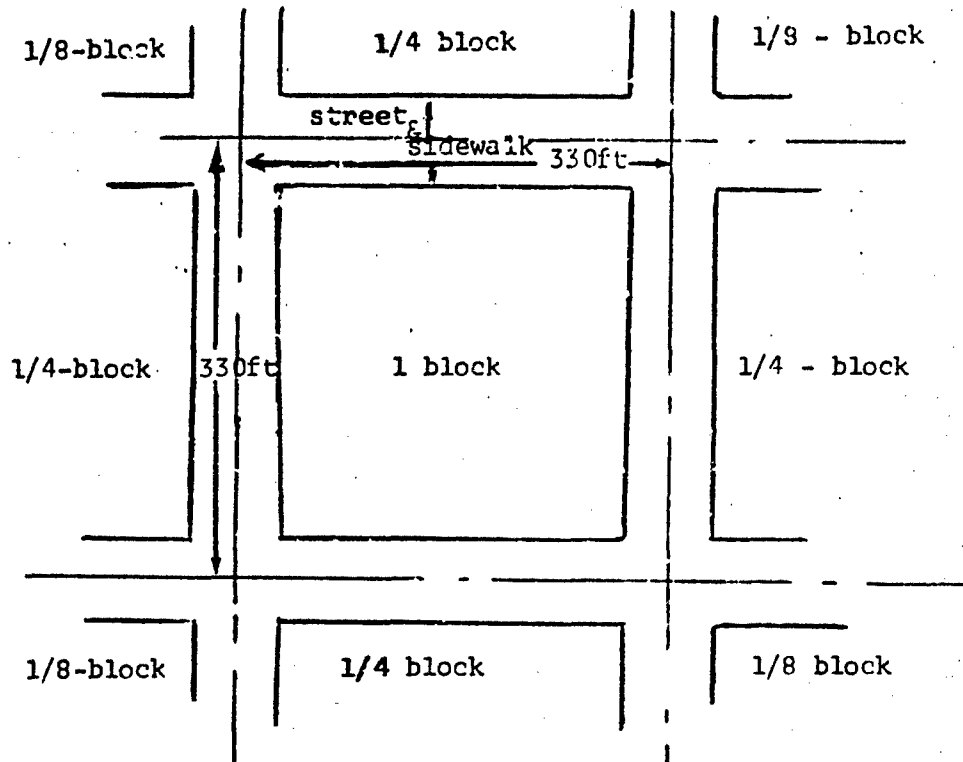


FIGURE 1. Typical Urban Area Model Size

The specifications and costs of the urban commercial area model are as follows:

Average ground area covered by construction

- Block size: 330 ft street center line to center line
- Street and sidewalk allowance: 60 ft
- Remaining area coverage factor: 85%
- Total number of blocks per model: 2.5
- Area =  $(330-60)^2 (0.85) (2.5) = 155,000$  sq ft

Average commercial building height: 7 stories

Type of structure

- Multistory, 4 to 10 floors of 5,000 sq ft to 20,000 sq ft each with at least one subgrade floor
- 20-ft x 20-ft column spacing
- 70 lb/sq ft floor loading
- Reinforced concrete and steel masonry (brick or stone) exterior
- Reinforced concrete stairs, stairwells, and elevator shafts
- Finished roof
- 8-ft floor height
- Interior cinder block walls
- No interior finish or service
  - No plaster
  - No electrical lines or fixtures
  - No plumbing lines or fixtures
  - No glazing
  - No elevator

Cost of building construction: \$7.00/sq ft.

Cost of street construction per running foot based on 40-ft street width and 10-ft sidewalk width on each side, including curbs, sanitation lines and water lines constructed to typical metropolitan Washington, D.C., requirements: \$50.00/running ft

Cost of storm sewer based on 30-in. pipe: \$10.00/running ft  
 Total cost of building construction  
     (7) (155,000) (7.00) = \$7,595,000.00  
 Total cost of streets, curbs, sidewalks,  
 sanitation and water lines  
     (330) (2) (4) (50.00) = 132,000.00  
 Total cost of storm sewers  
     (330) (2) (4) (10) = 26,400.00  
 Total cost of 2.5-block urban commercial area model \$7,753,400.00

The specifications and costs of the urban residential area model are as follows:

Average ground area covered by construction

- Block size: 330 ft street center line to center line
- Street and sidewalk allowance: 40 ft
- Remaining area coverage factor: 50%
- Total number of blocks per model: 2.5
- Area =  $(330-40)^2 (0.5) (2.5) = 105,000$  sq ft

Average residential building height: 3 stories

Type of structure

- Town house including basement
- 20 ft to 30 ft between party walls
- Masonry and wood construction
- Finished roof
- Internal bearing walls wood studs or cinder block
- 8-ft ceiling heights
- No interior finish or service lines
  - No plaster or wall board
  - No plumbing lines or fixtures
  - No electrical lines or fixtures
  - No glazing

Cost of building construction: \$5.00/sq ft

Cost of street construction per running foot based on 30-ft street width and 5-ft sidewalk width on each side, including curbs, sanitation and water lines constructed to typical metropolitan Washington, D.C., requirements: \$30.00/running ft

Cost of storm sewer based on 30-in. pipe: \$10.00/running ft

Total cost of building construction

(3) (105,000) (5) = \$1,575,000.00

Total cost of streets, curbs, sidewalks,  
sanitation and water lines

(330) (2) (4) (30) = 79,200.00

Total cost of storm sewers

(330) (2) (4) (10) = 26,400.00

Total cost of 2.5-block urban residential  
area model \$1,680,600.00

### III. URBAN ENVIRONMENT AND MISSION MODELS

A prior step and partial alternative to constructing full-scale physical models of portions of urban communities in which to test and evaluate actual equipment would be to generate (simulated) environmental and mission models for urban conflict. The models would provide criteria against which characteristics of equipment available for use in urban conflict could be evaluated and would also identify new equipment requirements. The models would be derived from

- Descriptive models of representative urban communities;
- Identification of the various levels of urban conflict intensity and
- A delineation of the tasks to be performed within and around the urban environment characterized to reflect the impact of the various levels of conflict.

#### A. DESCRIPTIVE URBAN COMMUNITY MODELS

The models of the urban communities contemplated could be structured to reflect a variety of urban communities in terms of geography, history, architecture, and physical properties. It is likely that major cities have many similar characteristics. A principle area of similarity would be the commercial/industrial sections. In the case of western industrialized nations, these areas are likely to be modernized or rebuilt to modern standards of structural design and materials and to handle modern transportation requirements. In the case of emerging nations, there are strong tendencies to pattern commercial and industrial areas to western standards. Many of the newer residential areas in major cities around the world probably also have similarities in structural design,

materials of construction, services and equipments, and transportation facilities. Finally, all major cities have sections of varying ages that are more or less representative of the historical development of the area.

It is reasonable to assume that each city could be categorized, in terms of physical characteristics, into a few representative sections. It is also reasonable to assume that some of these sections will be sufficiently similar that, for purposes of analytical models, composite sections could be "designed" to represent a large number of cities. For example, composite models of modern commercial sections and of modern residential sections could be described. Also, the possibility of describing composite models of "old sections" of cities representative of two or more countries of differing geographic location and historical development should not be summarily dismissed. Many "old town" thoroughfares have similar dimensions and construction. This is also true of housing, to some extent.

1. Example of an Analytical Model of an Urban Community

The descriptive information necessary to formulate characteristic urban models is essentially physical, and includes dimensions and geometry. The form of the data may be both quantitative and qualitative. Examples of information that would be pertinent to developing an analytical model of a city against which equipment for use in urban conflict could be evaluated are indicated below.

Urban Section

Type: Modern commercial

Size:  $3/4$  mile by  $1\frac{1}{2}$  miles, or 12 blocks x 24 blocks

Bounds: River on east side spanned by 2 highway bridges to modern residential section. Docks and harbor on south side. Adjacent "old town" on west side. New industrial section on north side extending out between "old town" and river.

## Streets

Major thoroughfares: 3 north-south streets--all extend from docks into industrial sections; 2 east-west streets--one starts at "old town" marketplace and extends to bridge at north end of commercial section. One starts at small park at edge of "old town" and extends to the southernmost bridge.

Width: 40 ft to 50 ft with 12-ft sidewalks.

Construction: Streets--6-in. thick concrete with 1-in. asphalt top. Curb--4-in. concrete. Sidewalk--2-in. concrete.

Average thoroughfares: Approximately 6 north-south extending from dock area into industrial section. Approximating 12 east-west extending from "old town" to major north-south thoroughfare along river.

Width: 28 ft to 32 ft with 8-ft sidewalks.

Construction: Streets--4-in. concrete with 1-in. asphalt top. Curb--4-in. concrete. Sidewalk--2-in. brick and cobblestone.

Minor streets: Approximately 8 north-south, some of which are segmented. Approximately 18 east-west, some of which are segmented.

Width: 12 ft to 15 ft with 6-ft sidewalks.

Construction: Streets--4-in. cobblestones. Curb--4-in. concrete. Sidewalk--2-in. brick and cobblestone.

## Bridges (twin structures--15 years old)

Width: 32 ft with 8-ft walkway on one side.

Construction: Steel truss on four 12-ft x 32-ft reinforced concrete piers (60 ft on centers). Roadway--Steel and 8-in. reinforced concrete. Four-foot iron rail separating walkway from roadway. Electrically powered pivoting center span. Load limit--10,000 lb/axlc.



#### Storm Sewers

Four-foot concrete pipe, 12 ft below grade, under curbs on both sides of street running entire length of "major thoroughfares" and interconnected at their intersections. Three-foot concrete pipe 10 ft below grade under curbs in both sides of street running entire length of "average thoroughfares" interconnected at their intersection and emptying into the 4-ft lines where they intersect. Sewer entries at each corner except where corner is intersection of two "minor thoroughfares." No consistent pattern of storm sewers on minor streets. Four-foot lines empty into river at high water level.

#### Sanitary Sewers

Fourteen- to sixteen-inch cast iron pipe 8 to 10 ft below grade under sidewalks of "major thoroughfares" and interconnected at pipe intersections. Eight- to ten-inch cast iron pipe, 8 to 10 ft below grade under sidewalks of all "average and minor thoroughfares" interconnected at their intersections and emptying into 14- to 16-inch cast iron pipe where pipes intersect. Empty into river below water level.

#### Water Service

Four- to six-inch steel pipe 6 to 8 ft below grade under all sidewalks. Interconnected and valved at all intersections and valved at entry to each user. Water service comes from industrial section.

#### Gas Service

Three- to four-inch steel pipe 4 ft below grade under all sidewalks interconnected and valved at intersections and valved at entry to each subscriber. Gas service comes from industrial section.

## Electrical Service

Three-foot concrete conduits for service lines 4 to 6 ft below grade under all streets with man entry points at all street intersections and at intervals between street intersections. Transformers 6 to 8 ft below grade adjacent to man entry points. Electrical service comes from industrial section.

## Buildings

Approximately 20 percent of buildings 8 to 12 stories high, reinforced concrete, masonry curtain wall, (4-in. stone or brick veneer and 4-in. slag block backup), 70 to 100 lb/sq ft floor loading (flat slab, 8-in. thick concrete with #8 gage wire mat and 1/2-in. steel rods), 40 lb/sq ft roof loading (flat slab, 6-in. thick concrete with #6 gage wire mat and 1/4-in. steel rods), 25 percent glass.

Approximately 30 percent of buildings 6 to 10 stories high, structural steel, and masonry wall bearing structure (4-in. brick or stone veneer and 36- to 78-in. slag block backup), 70 to 100 lb/sq ft floor loading, (flat slab, 8 in. thick concrete with #8 gage wire mat and 1/2-in. steel rods, 40 lb/sq ft roof loading (flat slab, 6-in. thick concrete with #6 gage wire mat and 1/4-in. steel rods), 25 percent glass.

Approximately 5 percent of building 10 to 12 stories high, structural steel with aluminum curtain wall (1/8-in. gage mullions and 2- to 4-in. slag block backup), 70 to 100 lb/sq ft floor loading (pan slab, 4-in. thick concrete dome, 24-in. width and 18-in. ribs, with #8 gage wire and 1/2-in. steel rod), 40 lb/sq ft roof loading, (pan slab, 3-in. thick concrete dome, 36-in. width with #6 gage wire and 1/4-in. steel rod and 15-in. ribs), 60 percent glass.

Approximately 45 percent of buildings 2 to 4 stories high, masonry bearing wall (4-in. brick or stone veneer and 18- to 12-in. slag block backup) and steel primary support structure with wood joists, wood floor and wood and slag roof, 40 lb/sq ft floor loading, 40 lb/sq ft roof loading, 25 percent glass.

#### Fire Prevention Service

Fire hydrants located on every city block midway between intersections and on alternate sides of the street.

#### Street Lighting

Utility poles on all street intersection corners and every 150 feet between corners.

#### Transportation

Major bus routes on all major thoroughfares. Bus park and maintenance garage in NE corner of "commercial section" adjacent to "old town" and "industrial section." Gasoline stations scattered throughout "commercial section" at a density of about two every 24 to 30 square blocks.

#### Communications

Typical Bell Telephone System of type found in United States except only about 50 percent direct dialing. No long-distance direct dialing. About 80 percent of service is underground using electrical service underground conduits. Above-ground lines use steel utility poles located at curb.

#### River

About 180 ft wide running along western side of "commercial section." Twenty- to thirty-foot channel 40 to 50 ft deep with 1/2-knot normal current. Shallow at shore with rapid drop-off. Deep mud bottom. Rocky banks 6 to 10 ft high, bulkheaded for about 50 percent of length of "commercial section" starting at docks with remainder 30° to 70° rocky grade.

## Dock Area

Approximately 1000 ft of wooden piers and docking space suitable for small fishing craft only. Rest of dock area includes three modern structural-steel, reinforced-concrete piers, 200 ft wide, extending 750 ft into bay. Low-tide draft of 40 ft. Five hundred acres of modern warehouses and storage sheds servicing docks. Ten modern oil storage tanks.

## B. LEVELS OF INTENSITY OF CONFLICT

Seventeen more or less distinct kinds of operations may be identified which could involve combat in cities or the use of military forces in built-up areas. These are often part of a larger military operation. The seventeen situations, in rough order of increasing scope and intensity, are:

1. Show of force or show of flag
2. Supervision of a plebiscite
3. Peace-keeping
4. Pacification of an area
5. Blockade
6. Rescue
7. Relief
8. Evacuation
9. Protection of facilities
10. Post-disaster restoration and relief
11. Relocation
12. Siege
13. Urban disorders
14. Urban insurgency
15. Urban guerrilla warfare
16. Civil war
17. Conventional limited war

### C. TASKS FOR URBAN CONFLICT

There are a large number and variety of tasks and subtasks that must be performed in order to implement essential military missions under conditions of urban conflict. Examples of such tasks and the functions to which they contribute are illustrated below in tabular form.

<u>Function</u>	<u>Task</u>
Intelligence	Identify and map underground networks <ul style="list-style-type: none"><li>• Utility and service lines and pipes.</li><li>• Pipelines large enough to permit passage of men.</li></ul> Maintain surveillance <ul style="list-style-type: none"><li>• Over population movement patterns.</li><li>• Over crowd forming.</li><li>• Over infiltration and infiltration routes.</li></ul>
Command, control and communication	Maintain command communication with next successive echelon(s) <ul style="list-style-type: none"><li>• Via radio.</li><li>• Via wire.</li><li>• Via physical transport.</li></ul> Direction and control of fire support <ul style="list-style-type: none"><li>• Delivered from airborne vehicle.</li><li>• Delivered from ground vehicle.</li></ul>
Logistics	Cargo Transport <ul style="list-style-type: none"><li>• Ammunition</li><li>• Food</li><li>• Fuel</li><li>• Equipment</li></ul> Troop Transport <ul style="list-style-type: none"><li>• Combat</li><li>• Security</li><li>• Support</li></ul>

Function

Task

Tactical Operations

Reconnaissance and target location

- Via direct trooper action.
- Via manned sensors.
- Via remotely operated sensors.

Search and destroy (locate and attack enemy positions)

- Via direct trooper action.
- Via manned sensor-weapon platform.
- Via remotely operated sensor-weapon platform.

Maintain surface transit routes

- Lay portable road segments on cratered, rubble-strewn or barricaded streets.
- Clear and repair barricaded and rubble-strewn streets.

Demolition

- Breach masonry walls or structures (for entry by men, equipment).
- Breach fortified walls (for entry by men, equipment).
- Demolition of obstacles (barricades, large pieces of debris, burned-out vehicles, etc.).

Threat neutralization

- Physical isolation and containment.
- Physical envelopment to facilitate surveillance.

Vertical envelopment

- Scaling walls and buildings.

Population Control

Sanitation control

- Garbage and trash removal.
- Garbage and trash incineration.

#### D. URBAN ENVIRONMENT AND MISSION MODEL MATRIX

The urban environment and mission model matrix is the device by which criteria for equipment capability can be established and in which characteristics of equipment can be evaluated and new equipment requirements identified. A "first cut" example of a matrix has been developed and is presented here (Fig. 2) to illustrate the concept and indicate its feasibility. The REVAL-WHEELS Report,\* dated 1 March 1968, was used as background in designing the matrix.

Essentially two types of data would be listed in the matrix. One of these can be termed "boundary conditions" in the sense that it indicates an envelope in which the equipment must perform. The other type of data to be listed in the matrix describes the physical design or performance characteristics of the equipment and can be termed "equipment capability." Thus equipment can be evaluated against boundary conditions and against equipment capability of other candidate equipments. In some instances, factors in the matrix will be so constructed as to be indicative of both a boundary condition and an equipment capability. Factors of this type will be identified in the subsequent description of the matrix.

The matrix is divided into four major sections titled "Scenario Factors," "Equipment," "General Mission Factors," and "Specific Mission Factors." Each is discussed briefly below. For each set of scenario factors, there will be one row of entries in the matrix for boundary conditions and one or more rows of entries for equipment capability.

##### 1. Scenario Factors

The "Scenario Factors" section of the model matrix delineates factors that control the environment and terrain in which the

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\* U.S. Army, Assistant Chief of Staff for Force Development, REVAL-WHEELS (U), Final Report, ACSFOR Doc. Control No. 2802742, AD 388219, 1 March 1968. (S)

URBAN ENVIRONMENT																			
	Scenario Factors				Equipment														
						Roadway Surface and Structure Factors													
	Conflict Level	Urban Area Classification	Task			Tractive Performance $C_1 @ F_0$	Trafficability $C_2 @ N$	Ground Clearance		Trenches			Craters			Barricades			Bubble and Debris
								Type A	Type B	Type C	Type A	Type B	Type C	Type A	Type B	Type C	Type A	Type B	
Boundary Condition																			
Equipment Capability					Equipment Item #1														
Equipment Capability					Equipment Item #2														

FIGURE 2. Urban Environment and Mission Model



## ENVIRONMENT AND MISSION MODEL MATRIX

General Mission Factors	
1. Mission Statement	2. Vision Statement
3. Core Values	4. Strategic Objectives
5. Key Performance Indicators	6. Resource Allocation
7. Risk Management	8. Stakeholder Engagement
9. Communication Plan	10. Evaluation and Feedback

Transfer Factors	
1	2
3	4
5	6
7	8
9	10
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79	80
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93	94
95	96
97	98
99	100

[illegible]

# URBAN ENVIRONMENT AND MISSION MODEL MATRIX

General Mission Factors			
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Performance Factors	Vulnerability Factors	Specific Mission Factors
---------------------	-----------------------	--------------------------

[illegible]

### Model Matrix

equipment will be required to operate and indicates the generic types of equipment to be employed. The scenario factors include combinations of

- The urban area community classification in which tasks are to be performed;
- The level of intensity of the conflict under which tasks are to be performed; and
- The specific tasks to be performed.

The interaction or interfacing of the scenario factors will tend to establish the boundary conditions for general and specific mission factors and consequently will indicate the candidate equipments to be evaluated or will at least indicate characteristics pertinent to the consideration of an equipment as a serious candidate.

a. Level of Conflict Intensity. The level of conflict intensity will tend to establish the kind of military operation which will be conducted, the weaponry likely to be employed by both sides, and the magnitude of property and terrain destruction likely to be tolerable. Representative levels of conflict intensity include: peace-keeping; blockade; rescue, relief and evacuation; facility protection; siege; civil disorders; armed insurgency; guerrilla warfare; conventional warfare. A more detailed listing of types of operation was made under Section III-B.

b. Urban Area Classification. The impact of level of conflict intensity on each urban area classification (e.g., commercial, industrial, modern residential, "old town") must be considered since the set of physical characteristics generally associated with each class of area interfaces differently with conflict intensity and with equipment employed. This in turn would have an influence on the kind of equipment (e.g., vehicle chassis, ordnance, communication, protective armor) required to perform the tasks that are necessary to implement prescribed military missions.

c. Task. Basic tasks will range from those common to all classifications of urban environment at all levels of conflict to

those likely to be encountered in only one class of urban area at a single level of conflict. It should be noted that although a task may be applicable to two or more levels of conflict and in one or more classes of urban environment, since each level of conflict interfaces with each urban area classification to determine the physical conditions and bounds within which the task is to be performed, theoretically each task should be considered within the context of each set of conditions for level of conflict and area classification. It is noted, however, that in the real world several or many sets of conditions for level of conflict and area classification may interact in a manner which will produce physical environments that can be considered equivalent in their effect on equipment to be employed.

## 2. Equipment

The equipment to be evaluated to perform the task specified in each scenario set is listed in the equipment column in successive rows below the "Boundary Condition" row. All data shown in the respective equipment rows will represent "Equipment Capability."

## 3. General Mission Factors

The interaction of the scenario factors will tend to establish the boundary conditions for the general mission factors. General mission factors are intended to group factors that are common to many types of equipment. Typically, many military functions require or are predicated on mobility. Several representative functions are fire support, communications, command and control, logistic support, security patrol, and reconnaissance. For this "first cut" at a matrix, general mission factors were grouped under three major headings identified in the matrix as "Transit Factors," "Performance Factors," and "Vulnerability Factors."

a. Transit Factors. The "Transit Factors" section of the matrix, generally speaking, relates to equipment mobility. The intent is to group the definable factors that tend to deter mobility with the equipment characteristics that overcome these deterrents and contribute to mobility. The environment factors or physical

characteristics tending to deter mobility stem from the scenario factors--urban area classification (physical properties, weather conditions), the level of conflict intensity (type of conflict, types of weapons employed), and the interaction of these factors. The factors or equipment characteristics that contribute to mobility are design related, having to do with geometry, power plant, power train, tractive mechanism, and the like.

Transit factors have been subdivided into five sections, namely "Roadway Surface and Structure Factors," "Obstacles," "Maneuverability and Roadability Factors," "Gradability," and "Amphibiability."

- (1) Roadway Surface and Structure Factors. Roadway surface characteristics, roadway construction, and soil structure under roadways are pertinent factors in assessing equipment mobility, particularly under conditions of escalating conflict intensity and progressive roadway deterioration and destruction. Several parameters are considered pertinent in assessing equipment mobility under the range of environment and terrain conditions likely to be encountered during progressively more intense levels of urban conflict. These parameters are tractive performance, trafficability, and ground clearance.

Tractive performance and trafficability are intended to take into account the effects of roadway surface and roadway structure, the effects of equipment design and performance, and their interactions. The Department of the Army has expended considerable effort in developing parameters which contribute to a valid assessment of vehicle tractive performance and trafficability for off-road and cross-country environments. The insight and techniques thus gained could be applicable to the development of parameters for urban environments.

- (a) Tractive Performance. Tractive performance is suggested as one type of indicator of equipment capability to perform a single task cycle or sortie under conditions imposed by a specified scenario set. The methodology suggested is the measurement of the resistance and propulsive forces which affect the tractive-mechanism/roadway interfaces for the equipment being evaluated. It is contemplated that a rating system can be evolved patterned on the LLL System developed by the Land Locomotive Division, Mobility Systems Laboratory, U.S. Army Tank-Automotive Command (USATACOM). Under a technique patterned on the LLL System, the data tabulated in the model matrix in the tractive performance column, equipment row would be a composite roadway characteristic  $C_t$  (representative of the roadway condition for the scenario set in which the equipment is being evaluated), at which the equipment can achieve a prescribed minimum acceleration level. The acceleration factor  $F_a$  could be expressed as a draw-bar pull-to-weight ratio.

The tractive performance parameter, being derived from roadway properties, equipment characteristics, and the interaction of the two, can be designated as both a boundary condition and an equipment capability.

- (b) Trafficability. Trafficability is suggested as an indicator of equipment capability to perform a designated number of task cycles or sorties under conditions imposed by a specified scenario set. This factor is intended to reflect traffic density or traffic loading/roadway interfaces. The suggested methodology is to measure trafficability

on the basis of ground pressure characteristics exerted by the vehicle and the properties of the roadway (surface and structure) which the equipment traverses. The U.S. Army Waterways Experimental Station (WES) developed an empirically derived system which could provide a pattern for measuring trafficability in urban conflict situations. The data tabulated in the model matrix in the trafficability column and equipment row would be a composite roadway characteristic  $C_r$  (representative of the roadway condition for the scenario set in which equipment is being tested), at which the equipment can achieve a prescribed number of cycles or sorties  $N$ .

As in the case of the tractive performance parameter, the trafficability parameter can be designated as both a boundary condition and an equipment capability.

(c) Ground Clearance. The vehicle ground clearance factor is intended as a relative measure of vehicle mobility where road surfaces have been broken for a variety of reasons and the road structure penetrated. It infers that as long as the tractive mechanism reaches a stable ground layer at a depth not in excess of ground clearance, it will not "belly out" and will retain minimum mobility. This factor may logically be relocated under the "Equipment Factors" section of the matrix.

(2) Obstacles. The "Obstacles" section of the matrix is intended to cover the variety of hard objects that equipment is likely to encounter under the scenario sets associated with urban conflict. The type, size,

and shape of the obstacles should be based on urban conflict experience where available. Where real-experience data are not available, the scenario set (physical properties of the urban environment, conflict intensity, weapons employed) should be analyzed to determine probable types, sizes, and shapes of obstacles.

A simple two-dimensional geometric technique is suggested for evaluating equipment capability against hard obstacles as a first attempt at evaluation. A two-dimensional diagram of the obstacle would be presented to a two-dimensional diagram of the vehicle to test its ability to negotiate the obstacle without mechanical interference. It is recognized that this highly simplified nondynamic approach, in which the effect of vehicle velocity, pitch, roll, and yaw are not evaluated, is at best a first approximation. The effect of flexure or suspension of vehicle tractive elements is not addressed. The technique does not provide for traversing or approaching obstacles at intermediate angles, nor does it credit potential advantages for roll articulation or maneuverability. The inclusion of dynamic effects would be desirable; however, a reasonable, accurate methodology which might cost less than a full-scale test (where equipment is available) has not suggested itself. Correlation of the simple concept suggested with selected full-scale performance tests would be necessary and could lead to the generation of useful coefficients and a reasonably simple empirical technique in which the level of confidence is acceptable.

It is noted that data columns provide for as many as three sizes of many of the obstacle types. It is intended to imply that maximum, typical, and minimum obstacle size designations may be warranted.

However, this is not certain, and a single identification value per obstacle may be adequate.

In the matrix example presented herein, there is some potential repetition in the listing of data, in that certain data to be listed under "Equipment Factors" could just as well be presented in the "Equipment Capability" row under "Obstacles." This type of potential redundancy would be removed as the matrix is more fully developed and refined.

- (3) Maneuverability and Roadability Factors. There are two obvious aspects to equipment maneuverability and roadability in an urban environment. One is the physical constraints imposed by roadways and structures. The second is the size and design characteristics of the equipment. Both are treated in the model matrix. Roadway constraints are boundary conditions and are listed in the "Boundary Condition" row of the matrix. Equipment size and design characteristics are indicative of the equipment capability and are listed in the "Equipment Capability" rows. However, several of the equipment capability factors to be listed in the "Equipment Factors" columns could be indicated in the "Equipment Capability" rows under appropriate "Roadway Factors" columns. This type of potential redundancy should be removed as the matrix is developed.

- (a) Roadway Factors. Four types of roadway factors are suggested to indicate constraint on maneuverability and roadability for scenario sets in general. These are roadway widths, allowable axle loads, footprint pressures, and heights of underpasses and tunnels. At this stage of model matrix development, it is assumed that as much as



90 percent of the roadways in an urban sector can be grouped in three width categories, in three allowable axle load categories, and in three allowable footprint pressure categories. Although underpass clearance can be a serious problem, generally there are not many underpasses and it should be sufficient to indicate the approximate number and the minimum and maximum clearance heights which are likely to be encountered in the particular scenario set.

In addressing roadway widths, data inserted in each column would be the approximate percentage of the number of roadways p% in the urban area covered by the scenario set that is equal to or greater than the width  $w$  indicated. Thus the streets not accounted for would be that percentage left that is less than the smallest width. Allowable axle loading data would probably be inserted into the matrix in the form of a "not greater than" axle load allowable. Similarly, footprint pressure data should probably be in the form of a "not greater than" pressure allowable.

- (4) Gradability. Gradability is a generally accepted measure of transit capability. For a given scenario set it is probable that boundary condition roadway grades can be expressed as a maximum anticipated percentage (ratio of rise to horizontal distance) and as a maximum rate of change of grade. The equipment capability to traverse a grade can be determined from test or by analysis. Its ability to traverse large rates of change of grade is indicated by wheel base and ground clearance factors.

(5) Amphibiability. Streams, creeks, rivers and lakes are often found in and around urban areas and as such are an inherent part of the scenario. The amphibiability factors are essentially an indication of equipment capabilities to cross or overcome water obstacles. It is not clear at this stage what type of quantitative data can be developed or techniques evolved for these factors or whether the set of factors shown in the preliminary matrix is, in fact, the most appropriate one. However, there is no obvious technical reason why some reasonable basis for measurement of these types of factors cannot be made and the relative importance of achieving amphibious capability for some tasks is clear.

b. Performance Factors. Performance factors are essentially measures of vehicle capability. Some comment on the factors indicated as pertinent may be in order.

Maximum highway speed is suggested in recognition of the importance of quick response to an escalating situation. Maximum acceleration is similarly associated with quick response in moving equipment to a critical position where it is required and in removing it from a militarily untenable position. Acceleration is a measure of available power and power train efficiency and an indicator of agility.

It is suggested that range capability be evaluated, at least initially, both by highway range at a specified cruise speed and by urban range at a specified mission speed. For some tasks in a scenario set, endurance (a mix of transit time to and from the equipment's operational station and time on station, including idling time) may be significant in equipment evaluation. This would require development of one or more standard mission profiles representative of the task assignment.

c. Vulnerability Factors. The vulnerability of equipment to enemy action under different levels of intensity of urban conflict is of major importance. The approach suggested here is to indicate the possible susceptibility of the vehicle to mobility kill by showing one or more range/caliber combinations and/or HE charge-size/miss-distance combinations that would immobilize the vehicle. In addition, it is suggested that flammability ratings be developed for equipment.

#### 4. Specific Mission Factors

No effort was made to generate sets of specific mission factors for purposes of this preliminary model matrix presentation. Each category of equipment should have its own set of factors which would measure the effectiveness of the mission-oriented equipment (i.e., ordnance, wall scaling, road repair) as opposed to the general mission factors (which refer to locomotion systems, armor, etc.). In this vein, there might be sets of factors for such primary missions as: fire support; surveillance, reconnaissance, and patrol; troop and material transport; command and control; roadway clearance and repair; and sanitation. Examples of specific mission factors for firepower, logistics, and sanitation are presented in Figs. 3, 4, and 5, respectively.

Boundary Conditions	Scenario Factors				Equipment	Specific Mission Factors Firepower												
	Conflict Level	Urban Area Classification	Task			Weapon (Type, Bore )	Warhead/Projectile		Material	Thickness	Penetration	Range	Accuracy	Elevation	Traverse	Rate of Fire		

FIGURE 3. Specific Mission Factors for Firepower





#### IV. SUGGESTED AREAS FOR NEW OR MODIFIED EQUIPMENT

Pending implementation of the proposed development of an urban environment and mission model and the evaluation of equipment in this model, there are several identifiable tasks which occurred in urban conflicts of recent years which may be more effectively performed in the future by a judicious application of current and new technology to existing equipment. These tasks have been addressed in the several ways indicated below:

- Where seemingly suitable equipment is available but not normally used in urban conflict, it is identified.
- Where available equipment appears susceptible to more effective employment if modified, a conceptual modification is indicated.
- Where a new equipment prototype development for use in urban conflict suggests itself, the conceptual design is indicated.

##### A. PORTABLE ROADWAY EQUIPMENT

Essential tasks which must be performed during and immediately after combat require rapid penetration and traversing of the urban areas by a variety of vehicles, ranging from self-propelled artillery and tanks to logistic transport, command, communications and emergency evacuation vehicles. Major mobility problems will arise if the streets are cratered, covered with rubble, or barricaded.

Equipment has been developed for off-road and cross-country use which would have some application within the confines of cities to facilitate movement of wheeled and tracked surface vehicles. The bridge-laying tank is an example. However, the extent to which it can be effectively used in an urban environment is not clear.

Criteria would be desirable against which to measure urban requirements. Typically one could identify existing spans bridging rivers, streams, and ravines within city limits. One could also project trench and crater widths, and a range of sizes of masonry and other types of debris and obstacles likely to be encountered, based on type and materials of construction. It may be adequate to employ bridge-laying tanks of the type now available. Alternatively, urban terrain may impose a different range of portable roadway span requirements. At one extreme may be the requirement to provide immediate passage over damaged bridges wherein typical damage anticipated may require longer temporary spans than bridge-laying tanks can provide. At the other extreme, emphasis on crossing relatively narrow trenches, craters, and barricades with wheeled vehicles may permit use of shorter spans than bridge-laying tanks normally carry and to be effective it may be necessary for the span-laying vehicle to be capable of emplacing many of these portable sections in rapid sequence.

Cheap roadway spans are suggested for urban use in place of, or to supplement, the all-metal (steel) bridge spans carried by bridge-laying tanks. Prestressed spans plus forms in which to cast them could be provided to an "urban engineer company." As soon as there are prospects that the level of intensity of conflict will result in destruction of streets and roads, new spans could be fabricated and stockpiled. It is noted that dimensional tolerances for prestressed concrete are normally greater than for fabricated metal structures. Any delivery and placement system for prestressed concrete roadway sections would have to take this into account.

Mat-type sections, possibly a modification of landing mats, have potential utility for emergency use as a portable roadway section. In this instance it is suggested that the mat could be laid over small craters, narrow trenches, and rubble to provide sufficient surface smoothing and continuity to permit essential vehicle transit.



There are several factors critical to effective use of vehicles to lay portable roadway sections in urban environments. The vehicles must be capable of quickly traversing routes available to the locations where roadway sections are required regardless of street widths or terrain. Vehicles must be sufficiently maneuverable within the constraints of street widths and street conditions to lay the roadway sections where required. Tasks must be performed under all levels of intensity of urban conflict. It is evident that tracks or puncture-proof tires and armor are required. However, more compact vehicles than the bridge-laying tank now available may also be desirable for urban tasks. Corner turning and combined on-road/off-road mobility exhibited by the GOER class of vehicle makes the type of articulation design employed therein a candidate for use in vehicles used for laying portable roadway sections. The straddle vehicle configuration has a unique potential for delivery and placement of a variety of types of portable roadway sections. The prospect of mating compatible and pertinent characteristics of the GOER and straddle designs warrants consideration.

In addition to the employment of surface vehicles to emplace portable roadway sections, the use of helicopters would have particular merit and could be extremely effective under the appropriate conditions. Helicopters have already been used both industrially and militarily for material delivery and equipment erection. If helicopter transport is to be an alternate mode of portable roadway delivery and emplacement, the portable sections should be designed to be compatible with the delivery helicopter. If the helicopters will require special handling equipment, this should be included in the program.

The utility of equipment such as portable matting is dependent on the character and size of debris to be covered. Special demolitions may be useful to break up excessively large pieces of rubble. Since portable roadway equipment is likely to be laid while under enemy fire, the critical parts of the laying vehicles, including the operator's compartment, should be adequately armored.

The importance of designing the portable roadway equipment to be susceptible to easy removal (i.e., preferably no more difficult than emplacement) and to be reusable is self-evident.

#### B. ROAD CLEARANCE AND MAINTENANCE EQUIPMENT

Requirements to carry out routine tactical operations and maintain population control during all phases of urban conflict directs interest to equipment capable of performing emergency debris clearance and street repair sufficient to allow access to and through populated areas and areas housing essential urban facilities. The construction industry and the material-handling industry represent a large reservoir for selection of equipments for street clearance and repair. These include bulldozers, rock crushers, loaders, scrapers, impactors, cranes, straddle vehicles, dump trucks, tree chippers, and others. A wide variety of construction and material-handling equipment is already employed by military engineer and construction battalions. Their designs in general tend to reflect commercial/industrial requirements on the one hand and military requirements associated with combat and logistic functions in rural, open, and rough terrain on the other.

It is not clear that the various levels of urban conflict would generate a need for performance or design characteristics other than what is now available. On the other hand, the variation in environment suggests some potential areas of difference that should be considered. Factors such as street dimensions and the need to minimize property damage may suggest a different emphasis in trading off between such features as amount of materials handled per unit time, size of equipment, range and flexibility of motion of material-handling mechanism, torque available for material handling and for locomotion, transit speed, transit range, vehicle agility including turn radius, and forward and backward mobility. Similarly, use in the urban environment may influence human engineering features and operator protection provisions, including type and location of armor. Vulnerability

requirements may require special consideration for countering booby traps and mines in the city environments. This might take the form of special kits or attachments for detecting, sweeping, detonating, or otherwise neutralizing such hazards.

### C. LOCOMOTION SYSTEMS

Mobility problems arise during urban conflicts due to enemy action directly on vehicles and due to the effect of this action plus the effect of friendly firepower on the terrain. The enemy can readily avail himself of good concealment close to and across vehicle routes. Enemy proximity makes vehicles susceptible to small-arms fire, hand grenades and other hand-delivered or homemade weapons, as well as heavier weapons. Vehicles will have to pass through areas infiltrated with or controlled by enemy forces which may be mined or seeded with passive obstructive devices such as nails and studs. As the intensity of the conflict increases and heavier caliber weapons are employed, streets will deteriorate and become cratered, trenched and littered with rubble of various sizes, shapes, and degrees of hardness. Such circumstances stress the need for improving vehicular tolerance of urban battle damage while at the same time improving vehicular capability to traverse battle-damaged urban terrain.

Vehicular mobility is generally measured by off-road, cross-country, and highway performance. It is evident that in many respects rough off-road, cross-country terrain may resemble masonry-littered, cratered city streets. In addition, the substantial improvements that have been made in the off-highway and cross-country capabilities of combat and transport vehicles may reflect the present technological limits for transit by ground vehicles over war-torn city streets. However, if the performance of the tasks associated with an urban conflict environment were given greater emphasis in vehicle development, different design characteristics might be stressed, resulting in changes in vehicle configurations, new vehicle designs, or, in some cases, special kits for use under urban conflict conditions.

One design area to be addressed is the tractive mechanism (the ground-contacting elements). Both of the types generally employed, namely wheel and track-laying, should receive attention.

Effort has been directed for some time at developing non-deflatable tires with good impact absorption and flotation characteristics. The criteria for acceptance appear to be predicated on pneumatic tire qualities. For extensive off-road or cross-country travel this may be understandable. However, for urban transit during periods of conflict the relative importance of impact absorption and flotation versus improved tolerance of battle damage should be re-examined.

Track-laying mechanisms have undergone substantial improvements in performance, reliability, service life, and riding quality. However, track-laying vehicles are still subject to immobilization if a track is damaged. The final drive for track-laying vehicles generally is the single set of sprockets driving the tracks. The tracks in turn transmit drive to the wheels. If a track is damaged or severed, drive to the wheels is interrupted and the vehicle is immobilized. In rugged cross-country terrain a total dependence on tracks may be understandable. Also, there may be less prospect of an enemy being within small-arms range to preclude repair efforts by the crew. During urban conflict, however, terrain conditions are likely to vary from street to street and from one end of a block to the other. Some alternate means of locomotion, even at reduced power, without any repair, appears desirable if the vehicle tracks are damaged (i.e., at least the capability to back out of an enemy line of fire or to move the vehicle to avoid blocking a street).

To reduce the incidence of immobilization due to track damage two complementary developments are suggested. One is a quick-release mechanism that would separate and uncouple the track. The release mechanism might be by mechanical, hydraulic, explosive cartridge, or some other device. The parallel development required is an alternate tractive system capable of diverting power from the track drive sprockets to at least one set of road wheels.

Narrow streets, fixed obstructions (such as utility poles and hydrants), and temporary obstructions (such as debris and craters) focus attention on the need for maneuverability with particular emphasis on corner turning, trench crossing, and obstacle clearance. Features such as pivot turns and good trench-crossing ability are associated with track-laying vehicles. This suggests that some vehicle types which normally employ wheel tractive systems be analyzed for their suitability for modification or redesign to permit field installation of track-laying kits when conflict circumstances so indicate.

The articulating chassis, or GOER, design is now being employed for two or three transport types. Compared to conventional wheeled vehicles of equivalent size, the GOER provides significant improvement in turn radius and mobility over rough terrain, obstacles, mud, and sharp inclines. Justification to use the GOER design appears to be primarily associated with performing tactical tasks in off-road, cross-country, and good highway environments. Appropriate emphasis on task performance in an urban conflict environment might provide strong incentives to employ articulating chassis designs for additional categories of vehicles.

Vehicular tolerance of battle damage can be improved by reducing the susceptibility of vehicles to fire and explosion. There have been continuing efforts along these lines, one of which is the development of a suitable jelled or otherwise less-volatile fuel. The bulk of this effort has been directed at aviation applications. However, the increase in violence and conflict in cities and the large number of vehicles that become involved in these conflicts clearly indicate the desirability of less-explosive fuels for ground operations. Another approach to reducing fire hazards in vehicles would be to place greater emphasis on self-sealing fuel systems and on designing integral fire extinguishing systems into critical parts of the vehicle.

Problems of urban mobility and maneuverability imposed by limited street widths, corner-turning requirements, and transit over broken and littered streets warrant the consideration of new, unconventional vehicles. The development of an ambulating quadruped

transporter was stimulated by requirements for off-road and cross-country transport over rocky, mud, forest, and jungle terrain. The demonstrated ability of an experimental ambulating quadruped to negotiate rough terrain, clear away obstacles and barricades, climb steps and kick aside debris suggests that it could be highly effective in an urban environment. It is particularly significant that this type of transporter may provide the degree of agility (as opposed to the maneuverability of wheeled or track-laying vehicles) required to traverse narrow "old world" streets originally constructed for foot traffic.

In order to improve the capabilities of wheeled and track-laying vehicles to traverse narrow streets, negotiate sharp turns, and perform essential tactical tasks in severely confined urban areas, consideration should be given to developing special designs exhibiting very narrow tread and very short wheelbase. The basic design might incorporate extendable (or telescoping) stabilizers to be employed as required by loading conditions during transit and when parked. In a similar vein, tactical circumstances may require delivery of large heavy equipment into streets or areas in which transporter turnaround, after delivery is made, is impeded or prevented by lack of space, enemy activity, or traffic density. This type of task suggests consideration of a vehicle incorporating dual, equal, and opposite directional drive systems and dual operator controls facing opposite directions.

Vertical takeoff and landing (VTOL) aircraft such as helicopters are an essential form of transport for bypassing impassable obstructions and flanking enemy positions. The use of helicopters to deliver ordnance, men, and supplies to specified points in minimum time has become accepted practice in urban combat and need not be discussed further here. Similarly, it has become accepted practice to use helicopters for surveillance, traffic control, population control, and other military and paramilitary functions. Helicopters and fixed-wing aircraft are used to provide quick response to requests for heavy firepower. There are practical limits, however, to the operation

of aircraft (helicopters as well as fixed wing) near or below the skyline or roof line of a city. Consequently, other forms of locomotion become necessary to ensure a vertical envelopment capability. (The use of ground locomotion systems for this purpose is discussed in Section IV-F.)

A variety of low-altitude man-carrying devices has been developed, ranging from flying platforms to flying belts. Such development generally appears to have reached the stage where an operational evaluation can be made. These devices may have inherent range and endurance limitations within the physical size envelope at which they could be effectively employed in urban conflict.

Serious efforts have been made to employ air-cushion technology as a high-speed land locomotion system over unimproved terrain. To date, problems associated with maneuvering and control, traversing barriers, vulnerability, cost, and efficiency have not been adequately solved in the context of use in an urban environment, particularly if use is intended during periods of active conflict. However, such vehicles may have high potential for use around the perimeter of urban areas.

A modified air-cushion or semi-air-cushion vehicle concept is feasible and is judged to have some utility for city combat. Conceptually the air-cushion vehicle would operate as the captive device of a conventional wheeled or track-laying vehicle. It could be connected to the mother vehicle by a rigid arm (or boom) or by a flexible hose or cable. In either event the primary power plant could be located on the mother vehicle. This permits the basic air-cushion vehicle to be relatively lightly loaded. If coupling were by means of a rigid arm, the arm could be used for partial support of the air-cushion vehicle, or the air-cushion vehicle could be counterweighted through the arm and in this manner further unloaded. Also, stability and control could be provided via the arm. The air-cushion vehicle could be fitted with a variety of sensors and might perform reconnaissance and detection functions for the mother vehicle. Displays from the sensors

and a control panel for the air-cushion vehicle could be placed in the mother vehicle. Types of sensors might include metallic material sensors (for mine detection), electro-optical sensors, and IR sensors. The air-cushion vehicle could look around corners and into low-elevation openings without exposing the mother vehicle or operators. It could also be fitted with a remotely controlled weapon to fire at the targets it senses. The alternative to installing the air source for the air-cushion machine on the mother vehicle and delivery through a rigid arm or flexible hose is to install the motor and blower directly on the air-cushion device. In the latter case the motor might be either gasoline or electric. If electric, power could be supplied from a generator on the mother vehicle.

In considering methods of locomotion that might generally be beneficial to a modern, highly mobile combat force, recognition should be given to the logistics problems imposed by mobility objectives and the possibility of reducing these while at the same time providing distinct possibilities of contributing to improved battle damage tolerance, reduced noise level, improved torque utilization and availability, improved acceleration, and, as a bonus, contributing to air pollution control without seriously degrading other important characteristics. Recognizing military interest to date in development of a closed cycle (steam or vapor) external combustion engine, this interest should be reemphasized now. The subject is large and cannot be treated adequately in summary fashion here. However, several points can be made:

- This type of engine can be built as a true multifuel engine. A wide variety of fuels can be used. For example, in Vietnam rice alcohol could be manufactured and used.
- Fuel could be used that would be far less volatile and explosive than gasoline.
- This type of engine would be quieter than the internal combustion engine.



- This type of engine provides maximum torque at zero engine speed which in turn contributes to (a) power transmission simplicity, and (b) better acceleration control through the power train to the drive wheels.
- This type of engine has a markedly lower smog emission than internal combustion engines.

There are at present some rather difficult problems to be solved. Probably the most difficult is the high-temperature lubrication problem. However, significant progress is being made by several commercial firms. The military could make a major contribution to this program at what may be a nominal cost by earmarking selected groups of vehicles into which the more successful engine developments could be installed and by then conducting real-time operational evaluation as part of routine use of the vehicles.

Referring to the previously noted need for a nondeflatable tire which would have improved life and reliability under combat conditions, it is suggested that greater emphasis be directed at developments involving:

- A nonhollow or (foam) filled tire whose resilience and shape does not depend on internal pneumatic pressure.
- A composite tire with a sidewall material compounded for improved resistance to flexing fatigue and abrasion and a tread material compounded for improved resistance to abrasion and sharp object penetration.

#### D. DEMOLITION SYSTEMS

Demolitions are often needed in urban conflict, and in many instances improved demolition systems would be desirable. Such instances range from the breaching of a stone, masonry, or concrete wall to the breaching of a low-density barricade or the breakup of large pieces of debris or equipment so as to facilitate their removal. The size of the breach required in a wall or barrier will vary with purpose.

It may be just large enough to permit the passage of a small warhead or it may be so large that a truck can drive through it. In current practice, shaped charges and plastic explosives are manually placed by sappers at the barriers to be breached, or, where standoff delivery is dictated, warheads incorporating such charges are fired at the barriers from conventional barreled weapons.

Alternatives to the sappers' hand placement of explosives would be desirable and are available in modern technology. Two conceptual designs are offered:

1. A telescoping arm that can be vehicle mounted, "loaded," and operated from behind an armor barrier to implant a charge at a selected point or a series of charges along a given contour. Remote detonation.
2. A remotely controlled, telescoping-nozzle device that can dispense liquid or jelled explosives at selected points or on a contour. Remote detonation.

Barreled weapons specially designed for city fighting would be preferable to the conventional fieldpieces currently used for demolition in urban conflict. Barreled weapons to be used in cities for killing a hard target, breaching a barrier, or removing an obstruction may realistically emphasize characteristics other than those normally found in weapons designed to provide artillery support against targets ranging from soft (men, material) to hard (bunkers, tanks) in rural and open country. For conventional fieldpieces, barrel and ammunition designs emphasize muzzle velocity, range, and accuracy appropriate to warfare in open terrain. In city combat, the physical characteristics of targets may be substantially the same as in open-country combat but the range typically may be 100 to 300 yards. Also, fewer opportunities and less space are available in cities for maneuvering--to flank a target, for example. If the breaching of obstructions is a prime requirement of urban combat, large-caliber weapons should be employed to make maximum breaches with minimum expenditure of projectiles. The

relatively short range requirements in cities permit low muzzle velocities, short rounds, and short barrels. By implication, a barreled weapon for urban combat can be smaller, lighter, and more mobile (since it can be mounted on a smaller vehicle) than a comparable weapon designed for long-range combat in open terrain.

#### E. RECONNAISSANCE, SEARCH AND DESTROY EQUIPMENT

Reconnaissance, search and destroy tasks in urban environments can be extremely difficult and hazardous. Enemy combatants have available a multitude of places of concealment, many of which place them close to exposed searching troops. Probably most of the places of concealment in cities can be classified as medium to hard targets. If the enemy is well acquainted with the area, as is often the case, he can maintain his routes of ingress and egress and he will be highly elusive.

There is an assortment of mechanisms and devices that could be engineered into potentially effective systems for greater mechanization of urban search and destroy operations. Such systems are interesting because they hold promise of reducing troop casualties and increasing troop effectiveness in locating hostile targets and clearing buildings.

A variety of telescoping or folding mechanisms for raising platforms from ground level to heights of several stories are commercially available. These mechanisms, operated hydraulically, pneumatically, or electrically, are routinely used in replacing street lights, trimming trees, fighting fires, and making rescues. The mechanisms can be mounted on vehicles of any type, from tank to unarmored truck, that can support them stably and provide them with operating power. Mechanisms so mounted can be equipped with a variety of devices for urban combat and population control. Several configurations are suggested in the paragraphs that follow.

Boom and ladder mechanisms might be fitted with armored platforms or capsules on which various types of target search and detection equipment, including closed-circuit TV cameras, floodlights,

acoustic sensors, and IR sensors, were installed singly or in any combination. In addition, the platforms or capsules could be fitted with one or more machine-gun pods boresighted with the sensor(s). If manned, the platform would have the necessary controls and displays aboard; if unmanned, it would be controlled remotely either from the vehicle on which the boom mechanism is mounted or from a station external to the vehicle. Sensor displays would be at the control point in all cases. The purpose of the system would be to search for, locate, designate and, if the platform is armed, destroy snipers, machine guns, and other threats. If the system depended on external firepower to destroy a target, it could be fitted with a laser designator. If dual cameras, searchlights, gun pods, and the like were mounted on a single platform, there might be a potential for monitoring both sides of a street. But this might be better accomplished by two independently controlled platforms or by two separate and complete boom assemblies.

An alternative approach to the ferret function of an urban search and destroy mission is the use of a tethered flying platform to carry the sensor. This type of vehicle could achieve greater elevations than a vehicle-mounted boom. An unmanned, electrically powered (hence low-noise-level) flying platform (Section IV-J), tethered through its electrical supply cable to a ground vehicle housing the electrical power generator, is suggested as an initial design objective. The platform could be fitted with a variety of sensor equipment such as closed-circuit TV camera, floodlights, acoustic sensors, and IR sensor. It is difficult to determine unempirically whether this type of platform would be suitable for a laser designator in urban environments. Effects of recoil and inertia would likely preclude effective use of conventional automatic weapons. However, use of a recoilless weapon might be possible. Section IV-J indicates that this vehicle concept is not unique. There have been a number of programs to develop a flying platform, but not necessarily in this form, for use in urban combat. It is possible that the concept is far more appropriate for use in an urban environment than elsewhere.

Another approach to urban surveillance and reconnaissance lies in the use of a lighter-than-air ship as a sensor platform (Section IV-K). This type of aircraft might also serve as a weapon platform. An airship could be manned or unmanned and fitted with a variety of sensors and ordnance. It could be designed for low-noise-level operation. The availability of new materials coupled with low-speed, low-altitude and moderate-endurance requirements make the concept reasonable.

#### F. WALL AND BUILDING SCALING EQUIPMENT

The tactical advantages of clearing a building of hostile forces by starting at the top and working down to the ground floor has promoted the notion of vertical envelopment in urban combat. Several ways of accomplishing this tactic are discussed below.

The general suitability of helicopters for placing troops on building roofs in areas where minimum rotor clearance requirements are met hardly requires further comment. If building and roof strengths are adequate, helicopters can touch down and off-load. Where roof strengths are questionable, men and material can be lowered by slings, ropes or mechanized ladders. Also, constraints on touchdown or landing on understrength roofs could be overcome by laying down landing mats at disembarkation points to reduce footprint pressures to acceptable levels.\*

Flying belts and flying platforms, discussed in Section IV-C, could provide a means of very rapid vertical envelopment.

The boom, crane, and ladder mechanisms discussed in Section IV-E also have utility for scaling walls and buildings. Booms could be fitted with plain or armored platforms capable of lifting several men. The general conceptual approach here is that of an assault operation. Suppression fire could be directed at a target from behind a barrier or from an unmanned boom-mounted platform until the manned platform reached the floor designated for disembarking.

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\* This suggestion does not adequately consider problems of structural vibration which may be controlling.

The basic configuration of the bridge-laying tank lends itself to adaptation for scaling walls and buildings of modest or moderate height. The concept is similar to that of the vehicle-mounted, boom-hoisted platform except that the bridge structure in itself is an excellent example of how massive and rugged a scaling device could be provided and of the protection it could offer.

#### G. SYSTEMS AND EQUIPMENT FOR THREAT NEUTRALIZATION

On the supposition that it is not always necessary to kill a threat and that threats cannot always be distinguished from non-threats, some effort is appropriate to investigate potentially effective techniques for neutralizing threats. Two general approaches can be considered here. One is to temporarily disable the threat. The other is to isolate a potential threat or a possible threatening position so that it can be dealt with later on if necessary.

Temporarily disabling threats (by chemical means) is a well supported practice for which there are a variety of delivery mechanisms. Effectiveness may be improved by placing the chemical dispenser as close as possible to the threat without increasing exposure of the dispenser operator. Fitting a chemical dispensing hose and nozzle to a remotely controlled boom, crane, or ladder mechanism is one way of achieving this. The use of a tethered flying platform to carry a light-weight chemical dispenser or short-range gas grenade ejector very close to a potential threat position is another approach.

Isolating a potential threat from activities around it by very rapid emplacement of a physical barrier is feasible. Although this concept poses substantial logistic problems, there are political, economic, cultural, and humanitarian reasons for seriously considering it. The intent of this tactic would be to seal off, at least temporarily, the means of ingress and egress and to block the line of sight of a real or potential threat position. It is suggested that vehicles incorporating folding or telescoping booms could be fitted with nozzles suitable for dispensing quick-drying, fast-setting

plastic materials for sealing openings. The practicability of this concept might be dependent on such problems as how to cover large openings, such as open doors and smashed windows, with a "foundation" sheet on which the sealing material could be deposited. An alternative to implanting a barrier as indicated might be to simply cover selected buildings or faces of these buildings with nontransparent plastic sheets. (The sheets might be lowered from the roofs.) Once suspicious openings and even whole buildings were sealed or otherwise closed off either partially or totally, they could be "staked out" and bypassed. The rupture of a sealed area would confirm the presence of a potential threat.

The general concept of "neutralization" may also have merit with respect to reducing or precluding enemy activity from and reducing the incidence of loss of buildings housing records, articles of historic and artistic significance, and under certain conditions, even buildings in which essential urban utilities and equipment are housed. The approach that suggests itself here is to dispense lightweight, fast-setting plastics, such as styrofoam, from properly equipped vehicles directly into or on the buildings in question.

The use of a fast-setting plastic dispensing system might have particular significance when considered in the context of temporarily sealing off sections of underground passageways (e.g., sewers) or sealing entry and exit points. A major problem in urban warfare, of course, is that of precluding or restricting the use of such facilities by the enemy. Even the mere identification of which such facilities, if any, are being used by the enemy presents great difficulties.

#### H. SANITATION EQUIPMENT

Population control carries a responsibility for maintaining at least minimum sanitation standards. There is a variety of commercial and industrial sanitation equipment available, much of which is employed by military engineer forces. Several possible extensions of this equipment may warrant attention.

Transportable trash compressors are now available for use in industrialized areas to facilitate trash handling and removal. A very-high-pressure, vehicle-mounted compactor could be engineered if not commercially available. It would be extremely useful in maintaining sanitation services. In a similar vein, a mobile and possibly gas-fed incinerator would appear to have useful applications.

#### I. UNDERGROUND PASSAGEWAY AND UTILITY NETWORK LINE DETECTION

It is not clear that the technology, devices, and techniques available to and employed in seismic prospecting have been fully considered for use in locating and mapping tunnel networks in urban areas. (Further, if full-scale environmental and terrain models for urban warfare become tools for urban warfare equipment development--as they should, in our view--then such models could also provide reference signatures, or at least frames of reference, for seismic signal correlation.) Artificially generated seismic waves provide information on the configurations of rock layer, useful in oil and ore prospecting, and on the rigidity of shallow strata, useful in civil engineering. The success of seismology in such applications indicates that it should also be valuable in tracing underground tunnels.

In geological exploration, techniques and sensors have been developed and employed whereby sonic waves can be generated and the reflective, refractive, and absorptive characteristics of the ground around the generator and between the generator and sensors can be measured. These measurements are amenable to correlation with data from models of known subsurface structure, and the subsurface structure of the local area of interest should then be deducible. Operational problems with this kind of system would include requirements for filtering or identifying all irrelevant background noise, the need for mobility, provisions for acquisition of an adequate data library on wave propagation through various media, and expressions of the properties of such media in terms of the constituent parts.



It is contemplated that such a system could be developed for installation in vehicles. A development objective should be to so construct the system that it could even be operated covertly from carefully camouflaged passenger vehicles. This objective is directed at a capability to map the subterranean passageways and utility lines of a city during peacetime with minimum risk of discovery or offending a host government or a noncooperative urban administration.

In instances where mapping prior to urban conflict cannot be accomplished, the system should permit at least the "discovery" of underground tunnels, sewers, and utility conduits. It should also permit some tracing of tunnels and conduits and an indication of the direction of a "next continuing section" of a tunnel where it enters areas under the control of uncooperative or enemy forces.

#### J. FERRET VEHICLE

A brief analysis has been made to ascertain the technical feasibility of an unmanned flying platform for use in ferreting out enemy positions under conditions of urban combat. It is evident from work conducted to date that the concept has merit and a more detailed study is warranted. A tethered vehicle could be undertaken with reasonable confidence. A tethered vehicle approach is suggested in preference to an untethered design, at least for initial test and evaluation, for several reasons. These include:

- Stability and control problems associated with a free-flight flying platform are reduced if the vehicle is tethered, and problems can be better managed.
- A useful vehicle could be achieved at less risk and without jeopardy to the whole concept, such as would occur if the more ambitious free-flight concept were undertaken and the results were found to be inadequate.
- A tethered configuration could effectively employ an electric motor as a primary power source. The attendant low noise level is compatible with the ferret function.

Preliminary analysis has been made to ascertain the relative weight and size variations of electrically powered flying platforms designed to carry payloads ranging from 40 to 120 lb, including cable weight. The estimates are shown in Fig. 6. Gross weight estimates range from 85 to 90 lb for 40-lb payloads to 270 to 285 lb for 120-lb payloads. Depending on rotor design and geometric and dimensional constraints, the vehicle platform might range from as little as 4 ft in diameter up to 10 ft.

The comments herein are not intended to imply that the application of a flying platform to surveillance and reconnaissance is a new idea. The concept has been studied in the past for use in open battlefields. There the purpose has been to raise the sight line above ground level by raising aloft the viewing system, which could in fact be a man or a TV camera, to permit a less restricted view of a large area at relatively long range. In an urban application, the system would be utilized to raise the sight line to permit detailed viewing of a restricted area at close range.

An unmanned ferret vehicle could be flown and operated from a ground vehicle or from an airborne vehicle such as a helicopter. The ferret vehicle could be fitted with such pertinent equipment as a closed-circuit TV camera, floodlights, and acoustic or IR sensors. Effects of recoil and inertial forces on platform orientation and hence on CEF appear to preclude the use of automatic weapons. However, the use of recoilless weapons is a possibility and should not be ignored.

#### K. LIGHTER-THAN-AIR SURVEILLANCE VEHICLE

There appears to be some merit in considering a lighter-than-air ship as a surveillance platform for operation over and around urban areas. A brief parametric study has been made to indicate the order of magnitude of the relationship of vehicle size to useful load. The study was based on the use of helium gas, and assumed a unit lift of  $0.062 \text{ lb/ft}^3$  for helium. Information is presented in Fig. 7 relating

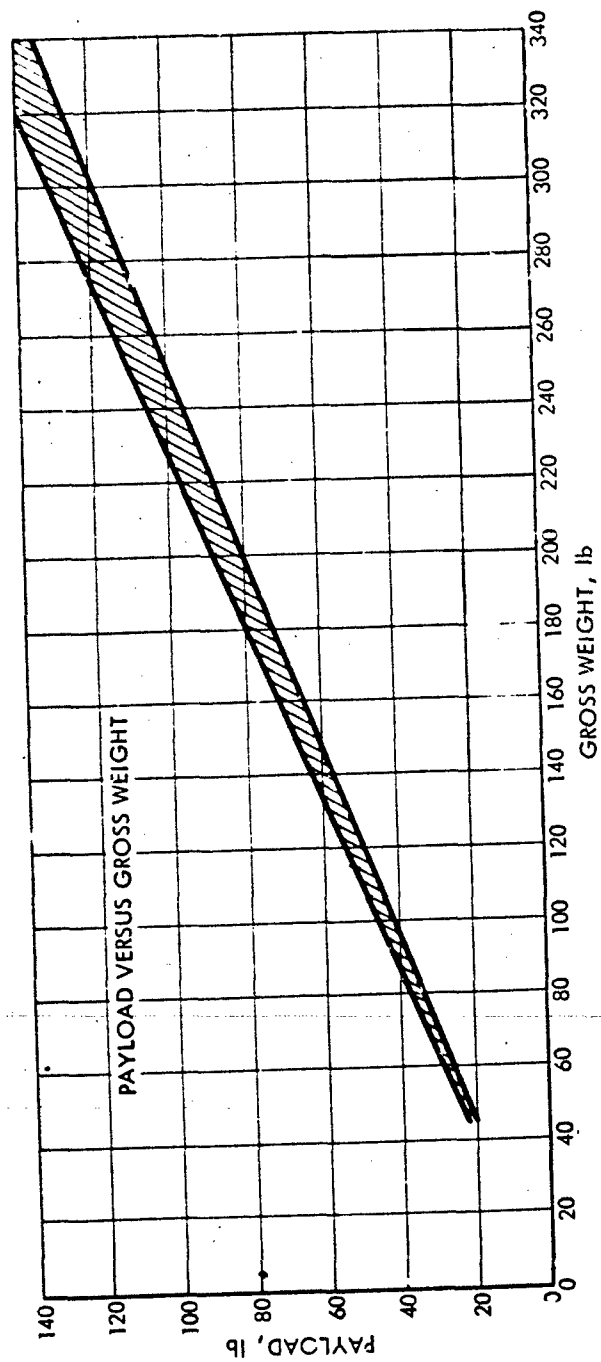


FIGURE 6 . Gross Weight Variations of Electrically Powered Flying Platforms  
Carrying Small Payloads

gas bag volume to static lift capability. For any volume, Fig. 7 indicates an estimate of minimum weight for the gas bag assembly and a basic gondola shell. Figure 7 also indicates a propulsion system allowance and a useful load allowance. The latter includes fuel, fuel tankage, and plumbing.

A 50,000-ft<sup>3</sup> gas bag can provide approximately 3000 lb of static lift. (Dynamic lift was not included, in the interest of conservatism). The bag and gondola shell weight is estimated at 1700 lb. A 300-lb propulsion system allowance would be reasonable for the installed weight of a 150-hp reciprocating engine, propeller, and controls. In the case of the 150-hp engine, this would permit cruise at about 35 knots. A 10-hr endurance requirement would require about 400 lb of fuel and tankage. The remaining weight allowance of 600 lb would be available for an operator and surveillance and communication equipment. The bag for a 50,000-ft<sup>3</sup> blimp would be of the order of 112 ft long and 30 ft at its maximum diameter for a typical length/diameter ratio of 37.5 (Fig. 8).

A 150,000-ft<sup>3</sup> bag provides an estimated 8850 lb of static lift. Of this, about 4950 lb is required for the bag and basic gondola. The 900-lb propulsion weight (exclusive of fuel and tankage) would permit about the same performance as this 50,000-ft<sup>3</sup> vehicle. To achieve the same endurance at cruise speed would require an estimated 825 lb of fuel and tankage, leaving 2175 lb available for crew and equipment. A typical bag for a vehicle of this size would be of the order of 160 ft long and 43 ft in diameter.

The above propulsive system estimates are predicated on reciprocating engines. Turbo-propeller engines could be used at some savings in installed weight. However, increased fuel consumption would tend to dissipate this advantage.

Results of current programs to provide quiet aircraft and helicopters could be adopted to reduce the noise level of the airship propulsion system. A cursory investigation of the suitability of electrical

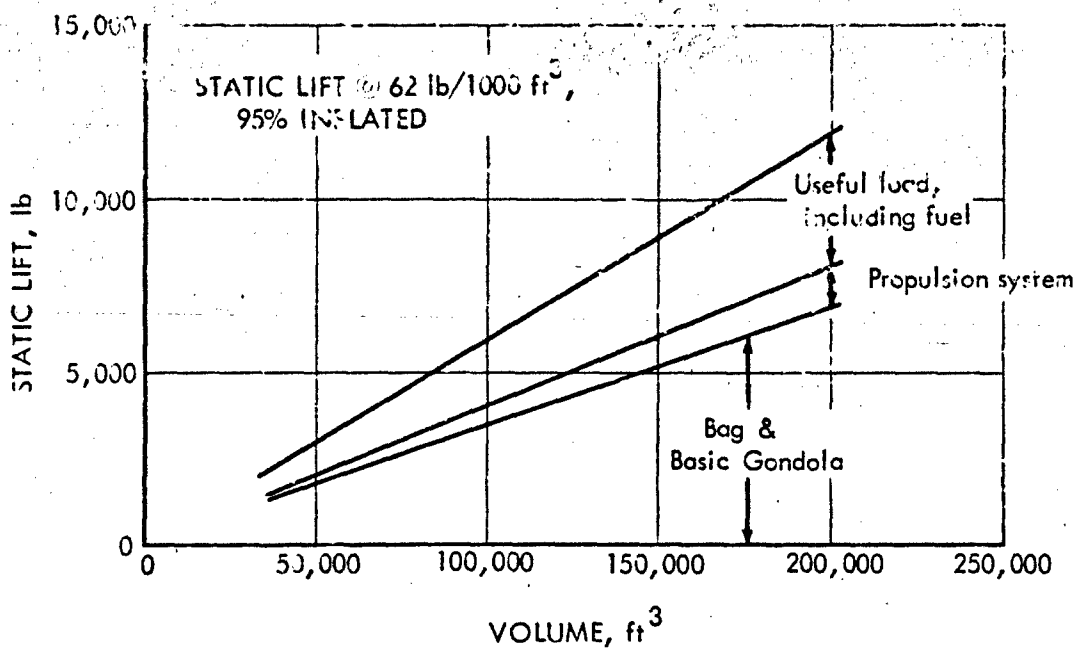


FIGURE 7. Static Lift Versus Volume

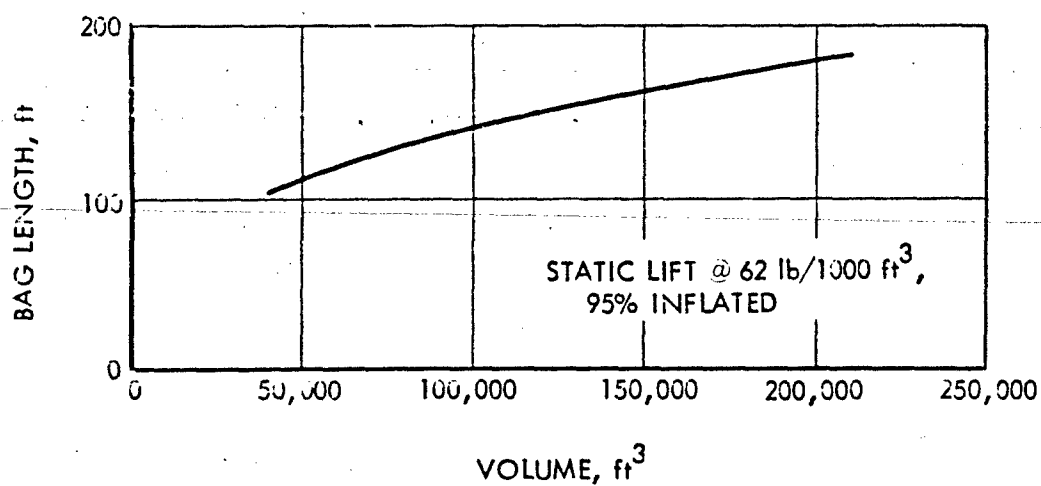


FIGURE 8. Bag Length Versus Volume

propulsion systems indicated that weights become excessive unless, possibly, fuel cells can be employed. However, fuel cell systems are expensive.

The data shown are predicated on use of helium to provide static lift. It is evident that a hot gas system, using engine exhaust as a hot gas source, could be employed to at least supplement a helium system.

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